The Langley Wind Tunnel Enterprise

by

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presented at

89th Semi-annual meeting of the Supersonic Tunnel Association, International

Hosted by the von Karman Institute for Fluid Dynamics
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History

Prior to 1994, all major wind tunnel facilities at Langley Research Center (LaRC) were "owned and operated" by research branches. For example, the Subsonic Aerodynamics Branch operated the 14- by 22- Foot Subsonic Tunnel, the Propulsion Aerodynamics Branch operated the 16- Foot Transonic Tunnel and so forth. These tunnels were used as tools to conduct research programs and "research results" were the prime focus. Schedule, productivity, cost , etc. were of much lesser importance. This had been the mode of operations for the past many years at Langley and clearly many significant advances in aeronautics for subsonic to hypersonic vehicles have been produced.

During the early 1990's, as the government in general and NASA in particular, was driven to be more customer focused, this mode of operation came under scrutiny. Our customers increasingly complained that schedule commitments were not being met which had potentially serious effects on

aircraft development programs. Because each tunnel was independently owned and operated there were inconsistent processes and procedures. Even data quality varied since a program might have to test in a series of facilities to cover a range on Mach numbers or test capabilities such as propulsion airframe integration or ground effects. Something needed to change.

In 1994 a program was initiated with the purpose of "re-engineering wind tunnel testing" at LaRC. (ref. 1) The mission of this effort was "to provide reliable, accurate research information to the aeronautical community in a timely manner. To accomplish this requires a focus on increasing productivity, cost effective operations, technical support that adds value, and the development of new facility capability and testing techniques." As a first step, seven major aero wind tunnels (see Table 1) were taken away from the research branches and placed under the management of a newly-formed Research Facilities Branch (RFB) within the Aerodynamics Division. Specific operational goals and measures of performance (metrics) were defined for the first time. These original goals and metrics are listed in figures 1 and 2. In addition, a structured program of facility calibrations and uncertainty analysis was undertaken to improve and control data quality. This is not to say that bad data had been produced before these changes but as customers began to ask for greater and greater accuracy (down to one or even one-half drag count), the old ways of doing business just were not quite good enough.

The WTE

In 1995 the concept of the Langley "Wind Tunnel Enterprise" or WTE was born. In an enterprise business model the three partners, the customers, the producers and the investors/stockholders, are brought together to manage the enterprise, in this case a significant set of major wind tunnels. As indicated in figure 3, our customers are the Aerospace Industry, the Department of Defense, NASA Program Offices, and Internal Research Programs while our Investors/Stockholders are again the NASA Program Offices, NASA Head Quarters and ultimately the American public. The Producers are the operators of the wind tunnels, the Research and Technology Group and the

Internal Operations Group at LaRC. Representatives of the three groups came together to actually provide guidance in the operation, management, and planning for the future of the LaRC wind tunnels.

Over the course of 3 years, some significant improvements have been made, some of which are presented in figure 4. Data accuracy was improved, and the desired uncertainty of one drag count was achieved in the National Transonic Facility (NTF). But upon reflection the question arose as to whether that level of accuracy was necessary or even possible in other facilities. Sometimes the timeliness of getting a test conducted and completed was improved. The cost of generating drag polars was cut in half but the tunnels still ran all the time so the goal of reducing operational cost by 30 percent was not even close to being met. In fact in 1997 the 14- by 22- Foot Subsonic Tunnel increased running time from two shifts per day, five days per week to three shifts per day, seven days per week, hardly the way to reduce overall operational costs. Tunnel reliability was improved but was hardly up to 100 percent and the number of polars (defined as 15 data points) obtained per hour was increased by about three. While these were certainly excellent trends, as evidenced by an overall increase in customer satisfaction from about 3.9 to about 4.5 out of 5, the total throughput of the tunnels was remaining almost constant (ref. 2). A tunnel such as the 16- Foot Transonic Tunnel that had been conducting one experimental investigation per month was still conducting one test per month. Improved reliability and improved procedures were yielding more wind on hours and many more data points but still one test per month, as indicated in figures 5 and 6. What was happening?

There is more to wind tunnel testing than just operating wind tunnels, as shown in figure 7. A typical test cycle will begin with a period of aerodynamic design where the external geometry of a concept is developed. This can last for years but for discussion it will be assumed to last a couple of months at which point planning for a test article can begin. Design and fabrication of a model will take about 5 months. Parallel efforts to define the final test matrix, choose proper

instrumentation, set up data reduction software and generally prepare the tunnel for testing will easily consume several months. Thus it can easily take half a year before the model and facility are ready. Considering that a relatively standard test lasts a month and allowing a month to analyze the results, the test cycle can and almost always does take on the order of 8 months. It is clear that, of the total time from the start of planning for a wind tunnel test to the delivery of analyzed data, the actual time spent in the wind tunnel is relatively small. Further analysis of the wind tunnel occupancy time indicates that on average at LaRC, only 21 percent is really wind on time. The remaining time is spent on handling the model or in downtime for maintenance, breakdowns, etc. The point of this discussion is that working hard to turn more polars per wind on hour is not going to have a significant effect on the total testing cycle.

The WTE Today

One question that can be asked as we approach the turn of the century is why do we continue to worry about wind tunnels at all? At Langley and the other Aeronautics Centers at NASA, they are the single most visible entity. It is hard not to see them from inside or outside the front gate and know that a sizable investment is in place. Wind tunnels are not going away as the CFD community once predicted, and at least for the near term future they are in very high demand by our customers. It would seem that really improving the test cycle from start to finish would be the best way to ensure that they are fully used for years to come.

With these thoughts in mind the WTE undertook a self evaluation in July 1997 to assess progress, to determine what processes, facilities and organizations were really "in" the WTE (fig. 8) and if needed, to set a new course with new goals. In a nutshell, it was decided that we were committed to the enterprise model and that we should steer away from the focus on operations only and include real integration of the customers and investors/stockholders and all processes which affect

wind tunnel testing at LaRC. In addition, the WTE began to expand with the addition of the 8-Foot High Temperature Tunnel, the Transonic Dynamics Tunnel, and most recently the Spin Tunnel.

New goals were developed on four fronts, as indicated in figure 9 to 12, to ensure that not only the technical and operational aspects of quality testing were improved but also the management and cultural environment was proper to support the people who ultimately have to make it all actually happen.

The new Technical goals are intended to align the WTE with the NASA Three Pillars document (ref. 3) by supporting Global Civil Aviation, Access to Space and Revolutionary Technology Leaps and by significantly reducing the total test cycle time over the next 10-15 years. To accomplish these goals, the WTE must meet all commitments to programs and customer expectations in a timely manner while maintaining technical and operational excellence. In addition the WTE must restore the once held confidence that value is added at LaRC by having technical expertise available to analyze results and provide recommendations to improve vehicle concepts.

Before these goals can be accomplished the needs of the staff of the WTE must be addressed. Management will demonstrate the importance of the staff by making the WTE a desirable place to work. This will happen through realistic work expectations and real promotion opportunities for all the staff. Also proper resources which are aligned with the goals must be provided. As a way of gaining leverage for increased capability, the WTE will actively encourage and participate in alliances with other wind tunnel service providers in the country to furnish the United States with the world's finest wind tunnel capabilities.

Lastly, the entire culture surrounding wind tunnel testing must change. The WTE will embrace business-like practices which will ensure that customers find the "better, faster, cheaper" testing

experience enjoyable and intellectually stimulating. This will happen through a culture of excellence in wind tunnel technology and operations created by a "university type" environment where the staff is properly educated so that the WTE is the repository of all our wind tunnel knowledge and new technology and testing capability are developed through WTE research.

To reach these goals by including all the processes and organizations which affect wind tunnel testing, a WTE process organization was developed to oversee the effort as presented in figure 13. This is not a line organization in that the people who are responsible for the various functions do not answer in an administrative sense to anyone in the WTE organization. Of course, their performance plans will reflect participation in the WTE and will be reviewed and evaluated by the WTE but their plans are held outside the WTE. This organization is in place to ensure that the management of the WTE includes the Providers, Customers and Investors/Stockholders with the overall responsibility for the WTE in the hands of a single Process Owner. There are two Process Managers who are responsible for the Strategic Development and Processes and the Tactical Development and Operations of the WTE. These two individuals are supported by a group of representatives from each organization within the WTE (Large Leaders Team) for the planning of long term improvements to the testing process and the Branch Heads of the organizations who directly support the day-to-day operations of the facilities (ETTD, FSSD, and ISSD). This process organization has been in place for roughly 6 months and does seem to be working well.

Summary

After 4 years of existence, the Langley WTE is alive and growing. Significant improvements in the operation of wind tunnels have been demonstrated and substantial further improvements are expected when we are able to truly address and integrate all the processes affecting the wind tunnel testing cycle.

References

1. Putnam, Lawrence E.: Wind Tunnel Productivity Status and Improvement Activities at NASA Langley Research Center. AIAA Paper No. 96-2260, 1996.

2. Kegelman, Jerome T.: Accelerating Ground-Test Cycle Time; The Six-Minute Model Change and Other Visions for the 21st Century. AIAA Paper No. 98-0142, 1998.

3. NASA Headquarters, Office of Aeronautics and Space Transportation Technology: Aeronautics & Space Transportation Technology: Three Pillars for Success. March 1997.

Langley Wind Tunnel Enterprise Re-engineering Goals

• Accuracy	Drag coefficient uncertainty < 0.0001 (reduce by factor of 5)
• Timeliness	Final data the same day, 1st look data "realtime"
• Cost effectiveness	30% cost reduction (operations)
• Value added support	Customer satisfaction
• Reliability	100% achievement of time commitments
• Productivity	Polars per hour increased by factor of 6

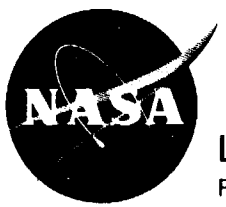

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Figure 1

Re-Engineering Wind Tunnel Testing

Measures of Performance

- Operational hours
- Data per occupancy hour
- Cost per data unit
- Maintenance cost
- Data accuracy, quality, uncertainty
- Plan to actual
- Workforce per facility
- Time to deliver data
- Facility downtime
- Model installation time

Langley Wind Tunnel Enterprise
Enterprise Model

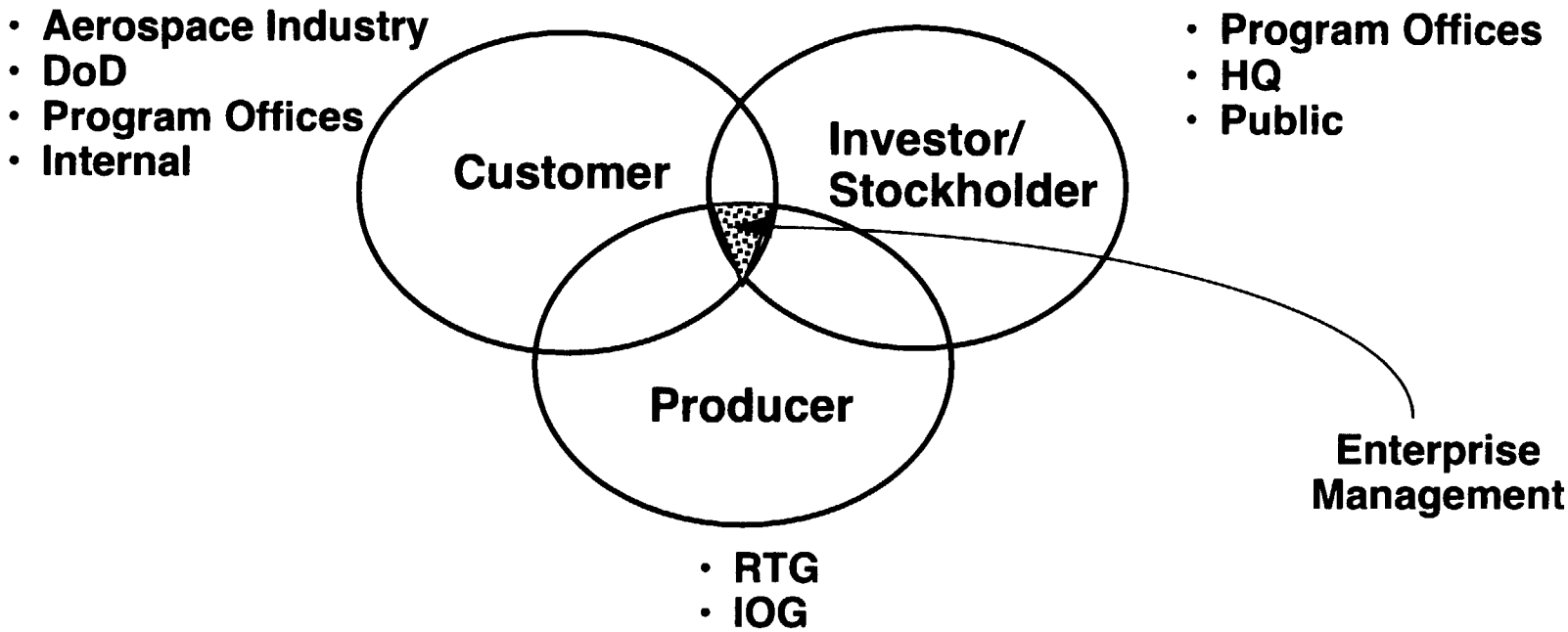

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Figure 3

Metrics for Major LaRC Facilities

Non-weighted Averages for NTF, 16-Ft. TT, 14- by 22- Ft. ST and UPWT

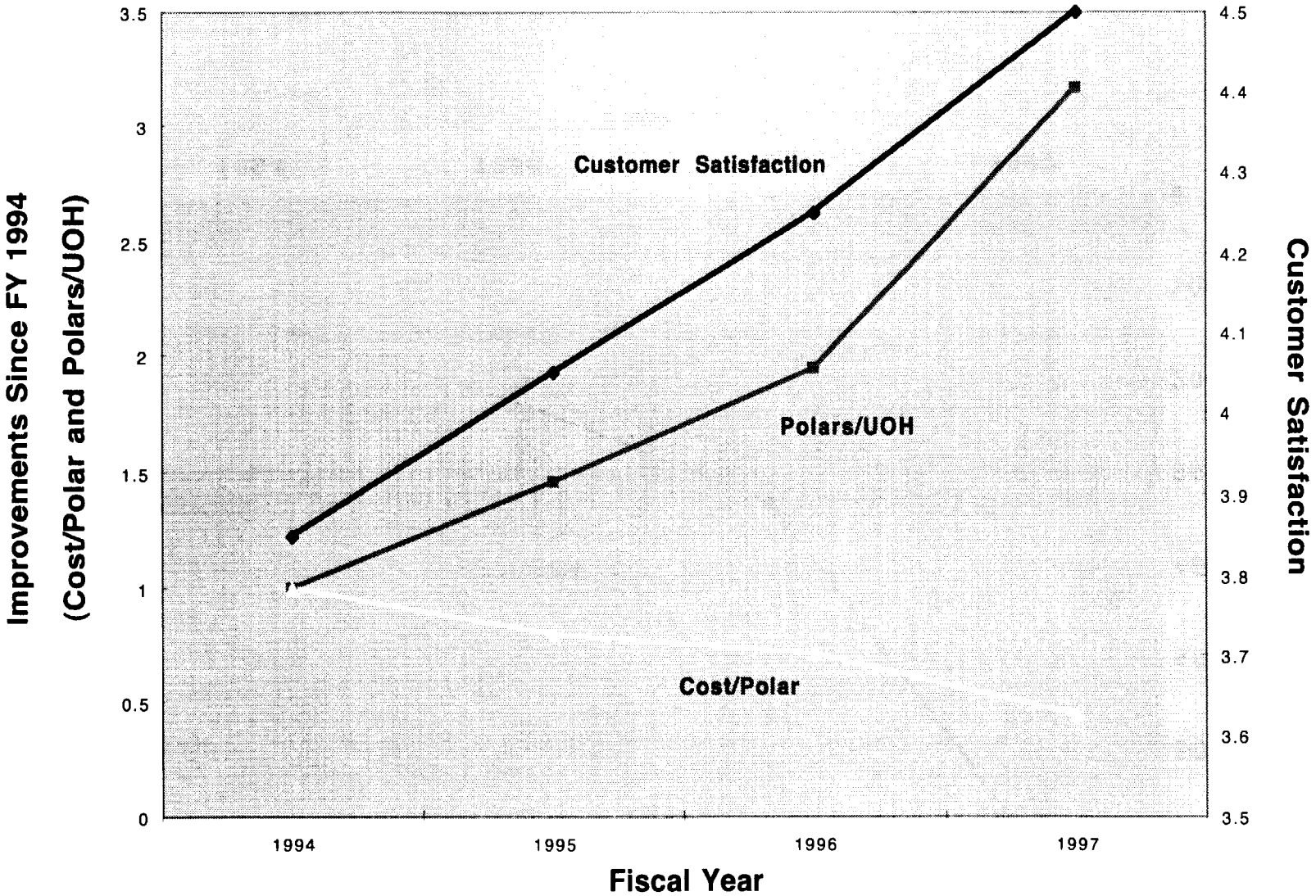

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Figure 4

Productivity Increases in 16-Foot Transonic Tunnel

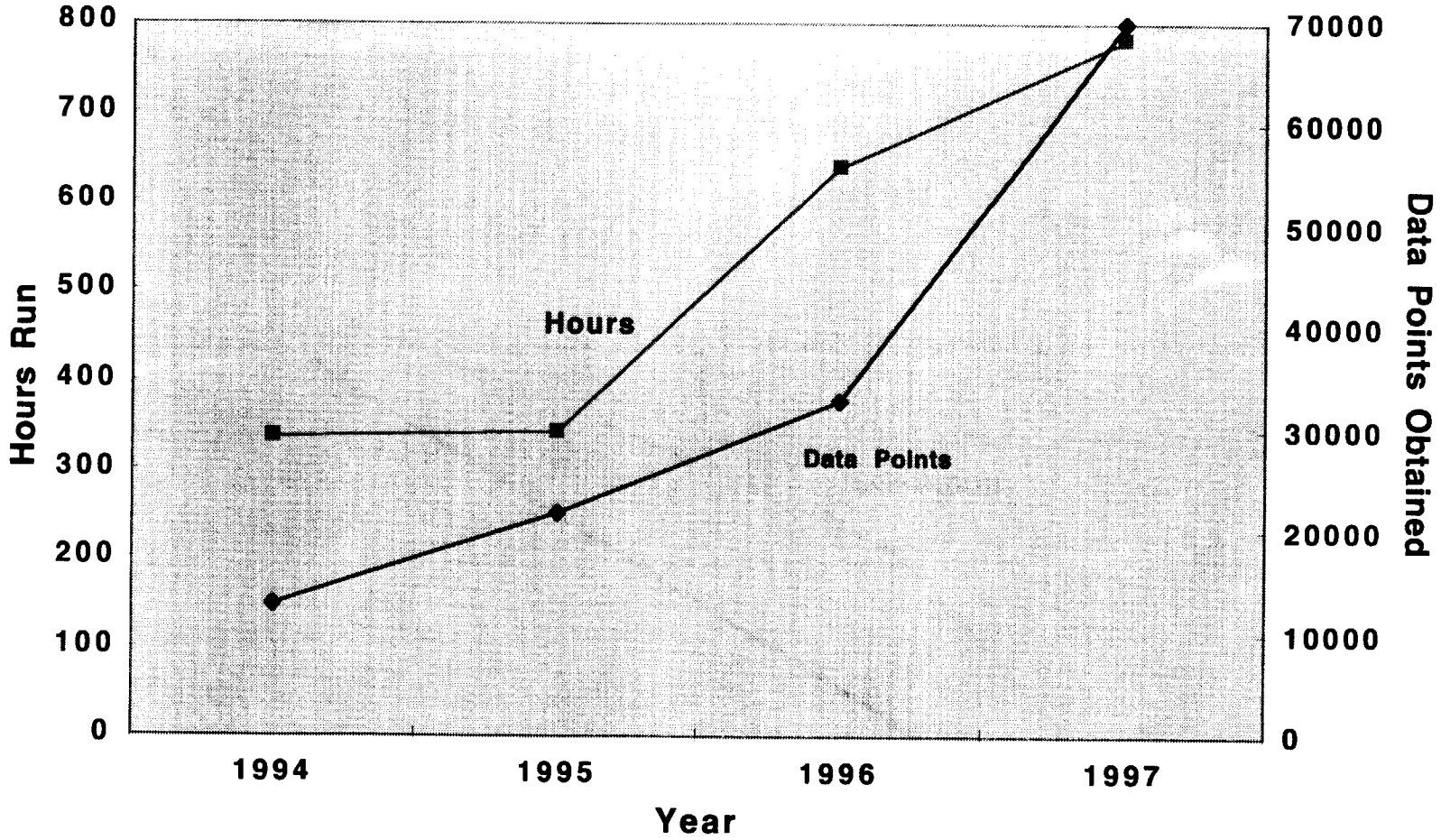

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Figure 5

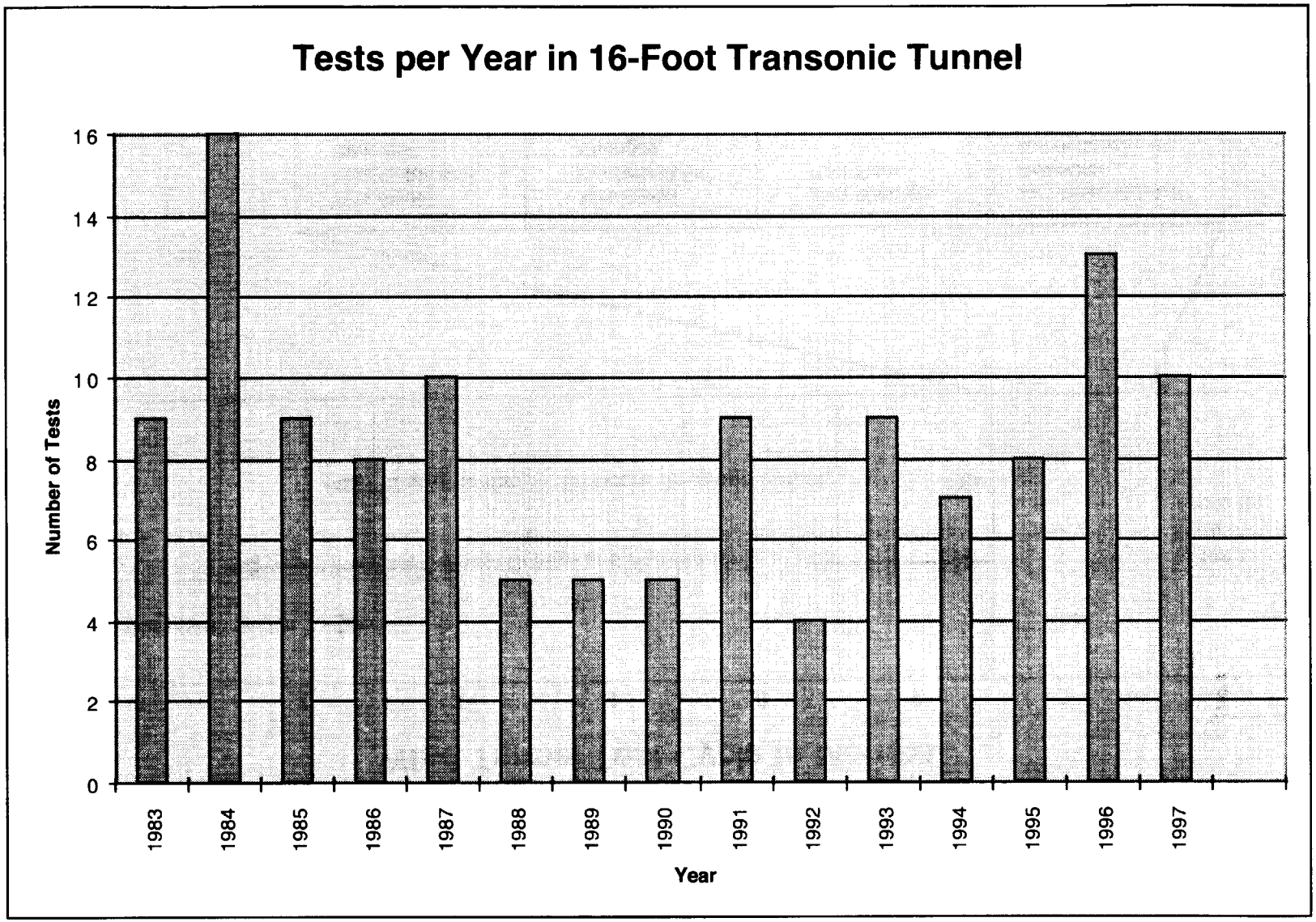

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Figure 6

What Happened?

There is more to wind tunnel testing than running the wind tunnel test

Wind Tunnel Test Cycle in Months

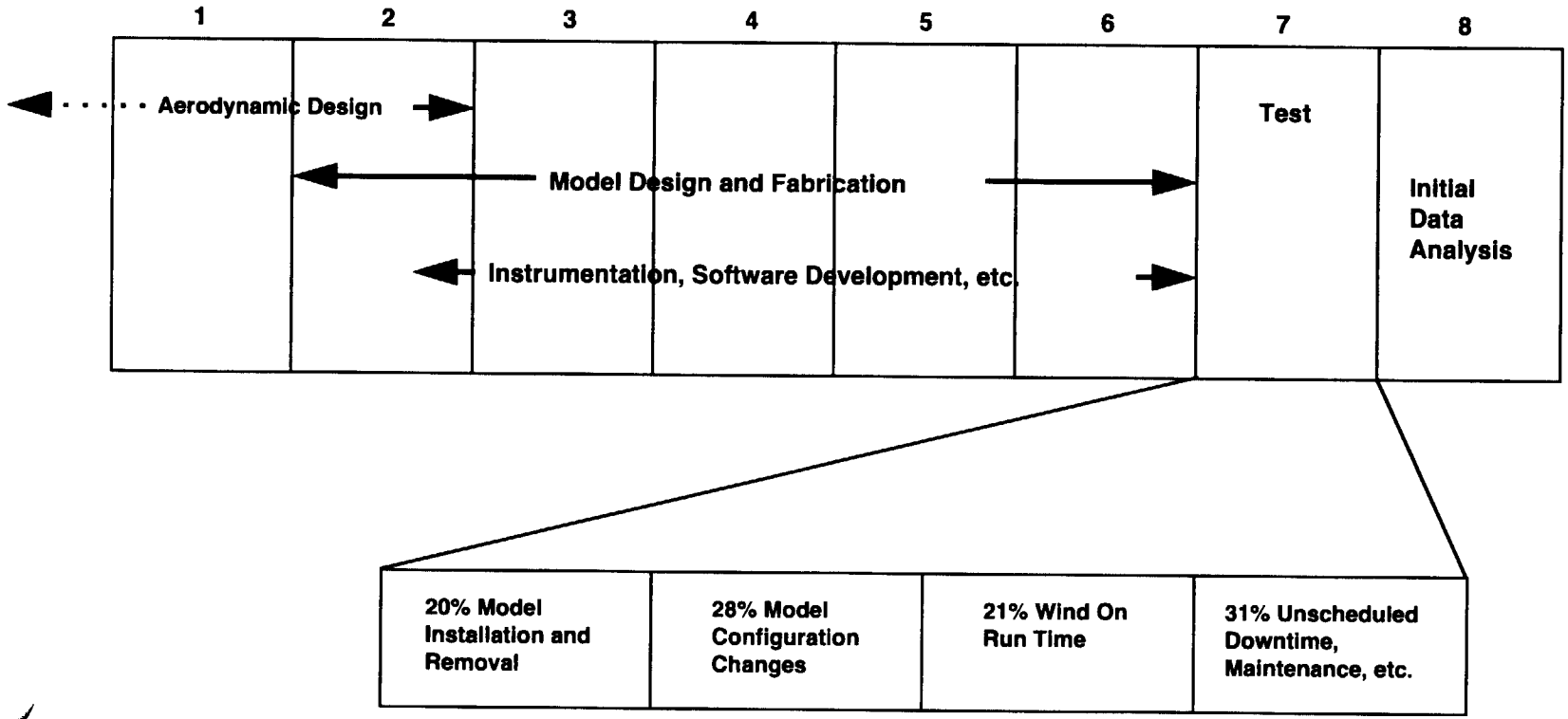

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Figure 7

Langley Wind Tunnel Enterprise

What is "in" the Langley Wind Tunnel Enterprise?

PROCESSES	FACILITIES	ORGANIZATIONS
• Tunnel Operations/Testing	• 14' x 22' ST	• AGDD
• Test Technology	• NTF	• FSSD
• Model Design/Fabrication	• 16' TT	• ETTD
• Zone Maintenance	• UPWT	• FSED
• Maintenance Augmentation	• LTPT	• ISSD
• Re-Engineering	• 0.3M Cryo	• FD
• Construction of Facilities	• JETF	• FMAD
• TSIP	• 8' HTT	• SD
• Management	• TDT	
	• Spin Tunnel	

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Figure 8

Langley Wind Tunnel Enterprise Technical Goals

By 2002, the WTE will provide:

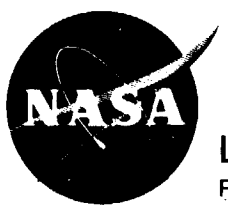
- **World-class subsonic, transonic, and supersonic test capability in support of NASA's goals for Global Civil Aviation, Access to Space, and Revolutionary Technology Leaps**

- **Fast, low-cost, concept-screening test capability across the Mach number range (0<M< 20) to support the development of next generation commercial and military aircraft and space launch vehicles**

The WTE fully integrates advanced wind tunnel testing into the next generation aircraft design processes by providing

- **An order-of-magnitude reduction in complete wind tunnel test cycle time by 2002 and two orders-of-magnitude reduction by 2010**

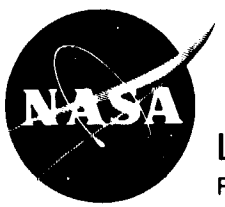
- **Virtual participation by entire test team for the complete test cycle**



Langley Wind Tunnel Enterprise Operational Goals

The WTE meets all commitments to programs and customers' expectations in a timely manner while maintaining technical and operational excellence through continuous improvement of ISO 9001-certified processes in the areas of:

- **State-of-the-art test techniques**
- **Efficient test processes**
- **Reliability-centered maintenance**
- **Value-added attitude**



Langley Wind Tunnel Enterprise Management Goals

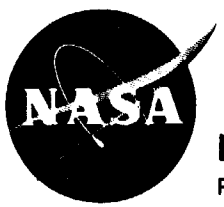
The WTE management demonstrates the importance of its staff by ensuring that the WTE is a desirable place to work by defining and implementing

- **Realistic work expectations by mid-1998**
- **True, dual career ladder for all WTE staff by 1998**

The WTE management demonstrates commitment to achieving the WTE Goals by mid-1998 through

- **Alignment of resources with goals**
- **Teaching and demonstrating the new way of working**
- **Documenting and communicating the message of the WTE**

The WTE encourages and participates in alliances with other wind tunnel service providers to furnish the United States with the world's finest wind tunnel capabilities



Langley Wind Tunnel Enterprise Cultural Goals

By 1998, the WTE embraces business-like practices and takes pride in providing world-class testing services to its customers by

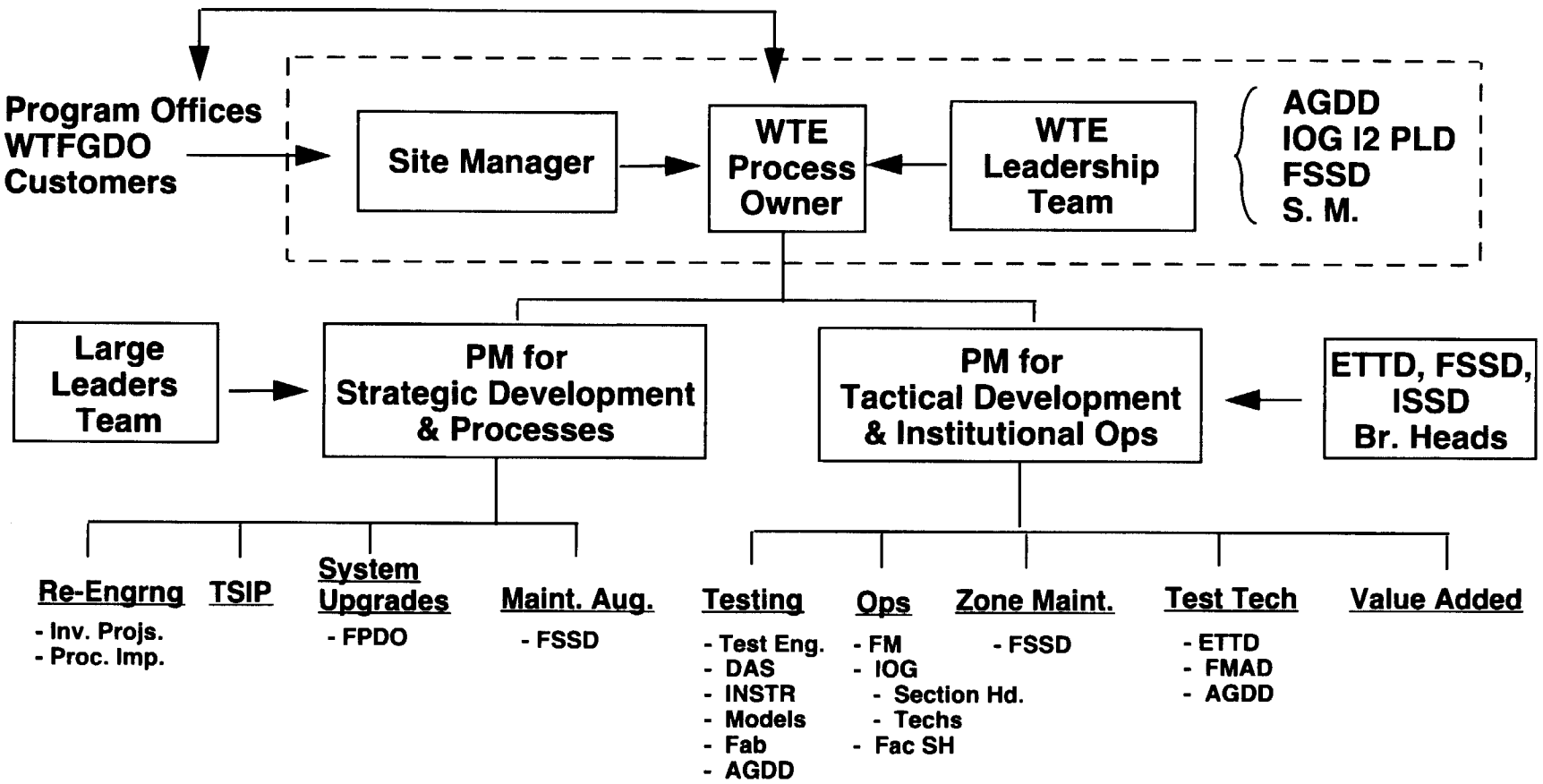
- **Promoting awareness of faster, better, cheaper means of providing wind tunnel services**
- **Making the customer a welcome part of the WTE and exceeding all expectations**
- **Making the total customer experience enjoyable and intellectually stimulating**

By 1998, the WTE creates a culture of excellence in wind tunnel technology and operations through creation of a "university" type environment which

- **Trains all workers in order to**
  - **Sustain and grow all wind tunnel skills**
  - **Provide repository of all our wind tunnel knowledge**
  - **Continually develop all technical staff skills**
- **Conducts research/development of**
  - **Test technology**
  - **New testing capability**

Langley Wind Tunnel Enterprise

How is the Langley Wind Tunnel Enterprise Governed?



Notes:

- ***Contractors supporting the enterprise are included***
- ***This does not represent a line organization***
- ***WTE focus is on integration of processes and available resources***

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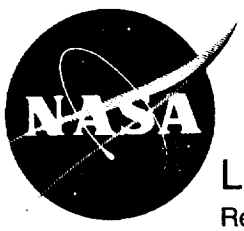
Figure 13



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